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(54) Heat shielded memory unit for an aircraft flight data recorder

(57) Solid state memory devices employed in crash survivable flight data recorders must be thermally insulated to prevent loss of stored data if the aircraft burns. To provide adequate thermal isolation at minimal size, the solid state electronic memory devices are encapsulated in pentaerythritol that exhibits a solid-to-solid phase transition at a temperature above the normal operating temperature of the memory unit, and below the maximum acceptable peak temperature of the memory devices. The pentaerythritol is surrounded by a thermal liner constructed of solid thermal insulating material. A metal enclosure houses and protects the thermal liner, the pentaerythritol and the memory devices.

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## SPECIFICATION

## Heat shielded memory unit for an aircraft flight data recorder

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*Background of the invention*

This invention relates to heat shielded enclosures for protecting and preserving a device or assembly from an otherwise destructive high temperature environment and, particularly, to heat shielded enclosures wherein enclosure size and weight is an important consideration. In the disclosed embodiment, this invention specifically relates to a compact, lightweight memory unit for use in a crash survivable aircraft flight data recorder wherein the memory unit is configured to withstand an aircraft crash and an ensuing fire with little or no loss of stored data.

Although there are numerous situations in which it is necessary or desirable to protect an item, device or assembly from deleterious exposure to a high temperature environment, shielding the memory device of an aircraft flight recorder system during crash and a fire presents extremely demanding design constraints. In this regard, in order to preserve flight data supplied to the memory unit by the flight data recorder data acquisition unit during a predetermined time interval immediately prior to an aircraft crash, the memory unit must be configured and arranged to withstand temperatures in excess of 1100°C (approximately 2000°F), experienced during a fire while simultaneously being constructed to endure crushing and penetration forces experienced either on impact or during secondary impact with other portions or pieces of the aircraft. Further, the memory unit of a flight data recorder system is subject to additional design constraints imposed by considerations generally applicable to aircraft equipment and systems, including constraints relating to size, weight, cost, serviceability and reliability.

Technical advances in the various electronic solid state device arts have led to high capacity electronic memory devices for nonvolatile storage of digitally encoded data, with programmable read only field effect transistor devices and bubble memory devices being two types of such memories. Because such devices are small and lightweight and exhibit high reliability, there has been substantial impetus for replacing the magnetic tape transports utilized in current flight recorder system designs with solid state memories.

Because of increased heat shielding demands, the currently employed technique of mounting a tape transport or other flight data recorder memory device within a cavity that is formed by encasing the memory device with a solid material that is a relatively good thermal insulator and surrounding that assemblage with a protective metal housing does not achieve the desired overall reduction in memory unit size and weight that might be obtained in flight data recorder systems employing semiconductor memory devices such as erasable programmable read only memories.

We have disclosed in our copending British Patent Application No. 2151410A an enclosure for thermally protecting one or more heat sensitive items from a high temperature environment, said enclosure com-

prising a thermal liner within an internal cavity of a housing, with the one or more heat sensitive items being located within but spaced apart from the walls of the thermal liner, the thermal liner being made of a solid material which remains solid when the enclosure is exposed to a high temperature environment; and a thermal insulator encapsulating the one or more heat sensitive items and exhibiting a solid to liquid phase transition at a predetermined temperature, the predetermined temperature being selected to maintain the thermal insulator in the solid phase when the enclosure is not exposed to the high temperature environment and being selected to allow conversion of the thermal insulator to the liquid phase when the enclosure is exposed to the high temperature environment. The thermal insulator is selected to have a phase transition temperature which is (a) above the peak temperature encountered under normal operation conditions, and (b) at or below the peak temperature objective for the device being protected.

*Summary of the invention*

This invention is based on the discovery that the thermal insulator of GB 2151410A may be substituted by one or more materials that exhibit a solid-to-solid phase transition rather than a solid-to-liquid phase transition. One such thermal insulator is an organic solid solution of pentaerythritol ( $C_5H_{12}O_4$ ). Pentaerythritol is a poly-alcohol having a tetrahedral structure having a central carbon atom attached to four outer carbon atoms that are located at the vertices of a regular tetrahedron. This material exhibits a melting point of between 258°C and 260°C, a solid state transition temperature of 184-185°C, and a latent heat of transition of approximately 72 calories/gram.

When the material that exhibits the phase transition reaches the transition point, it in effect serves as a heat sink since heat energy reaching that material is then utilized to convert the material from a solid state to a liquid (heat of fusion) or convert the material from one solid state to another. This maintains the maximum temperature attained during exposure to a high temperature environment at an acceptable level.

The invention accordingly provides an enclosure for thermally protecting one or more heat sensitive items from a high temperature environment, said enclosure comprising a thermal liner within an internal cavity of a housing, with the one or more heat sensitive items being located within but spaced apart from the walls of the thermal liner, the thermal liner being made of a solid material which remains solid when the enclosure is exposed to a high temperature environment; and a thermal insulator encapsulating the one or more heat sensitive items and exhibiting a solid to solid phase transition at a predetermined temperature, the predetermined temperature being selected to maintain the thermal insulator in a first solid phase when the enclosure is not exposed to the high temperature environment and being selected to allow conversion of the thermal insulator to a second solid phase when the enclosure is exposed to the high temperature environment.

The currently preferred embodiments of the invention are configured for maintaining solid state electronic memory devices of a flight data recorder at or

below a maximum temperature of 200°C (approximately 390°F) when the flight data recorder memory unit is exposed to a fire that produces temperatures of 1100°C (approximately 2000°F) for a period of 0.5 hours and the memory unit is left undisturbed for an additional 4 hours.

With respect to the physical configuration, the flight data recorder memory unit disclosed herein includes an outer housing constructed of metal that exhibits a high thermal conductivity and high resistance to crushing and piercing. An intumescent coating or paint is generally applied to the exterior surfaces of the outer housing for additional thermal insulation. An insulating layer of solid material that exhibits a relatively low thermal conductivity adjoins each interior surface of the housing to form a rectangular cavity that is centrally located within the outer housing. One or more printed circuit boards, which include the solid state electronic memory devices being protected, are mounted within a metal inner housing that nests within the central cavity with the synthetic wax material surrounding and encapsulating the printed circuit boards. Electrical connection between the solid state electronic memory devices and a remotely located flight data recorder data acquisition unit is facilitated by a flexible, ribbon-type multiconductor cable that interconnects the printed circuit board with an electrical connector that is mounted to the exterior of the outer housing. The detailed construction of a heat-protecting enclosure of the invention can be most readily appreciated by reading the Specification in conjunction with GB 2151410A.

#### CLAIMS

1. An enclosure for thermally protecting one or more heat sensitive items from a high temperature environment, said enclosure comprising:  
a thermal liner within an internal cavity of a housing, with the one or more heat sensitive items being located within but spaced apart from the walls of the thermal liner, the thermal liner being made of a solid material which remains solid when the enclosure is exposed to a high temperature environment; and  
a thermal insulator encapsulating the one or more heat sensitive items and exhibiting a solid-to-solid phase transition at a predetermined temperature, the predetermined temperature being selected to maintain the thermal insulator in a first solid phase when the enclosure is not exposed to the high temperature environment and being selected to allow conversion of the thermal insulator to a second solid phase when the enclosure is exposed to the high temperature environment.

2. An enclosure according to claim 1, wherein the thermal insulator is pentaerythritol ( $C_5H_{12}O_4$ ).

3. An enclosure according to either preceding claim, wherein each of the one or more heat sensitive items is a solid state electronic memory device for storing data which is to be recovered therefrom following exposure of the enclosure to the high temperature environment.

4. A crash survivable memory comprising an outer enclosure surrounding one or more memory devices and a layer of solid thermal insulation that lines the walls of the outer enclosure to form a cavity for

maintaining the one or more memory devices below a predetermined temperature limit when the memory unit is subjected to both a normal range of operating temperatures and a high temperature environment, wherein a thermal insulator fills at least a portion of the cavity and encapsulates each of the one or more memory devices, the thermal insulator exhibiting a solid-to-solid phase transition at a temperature that is no greater than the predetermined temperature limit and that is greater than the normal range of operating temperatures.

5. A crash survivable memory unit according to claim 4, wherein the thermal insulator is pentaerythritol ( $C_5H_{12}O_4$ ).

6. An airborne crash survivable memory unit configured for operation within a predetermined range of operating temperatures and for preservation of substantially all data stored therein when the memory unit is exposed to a predetermined range of high temperatures, which memory unit comprises:  
one or more solid state memory devices for storing the flight data information at temperatures up to a maximum acceptable peak temperature;  
an outer housing having an interior cavity region for containment of the one or more solid state memory devices;

a thermal liner positioned between the one or more solid state memory devices and the walls of the interior cavity region, at least a portion of the thermal liner being spaced apart from the or each solid state memory device; and

a thermal insulation that exhibits a solid-to-solid phase transition at a temperature that exceeds the predetermined range of operating temperatures but is below the maximum acceptable peak temperature, the thermal insulation occupying at least a portion of the region defined between the one or more solid state memory devices and the thermal liner to encapsulate the or each solid state memory device.

7. A memory unit according to claim 6, wherein the thermal insulation is pentaerythritol ( $C_5H_{12}O_4$ ).